Cover Story

Elevating Utility of Buildings with Hollow-core Precast Concrete Slabs

Photo © Steve Evans

By Jack Laken, P.Eng., B.Sc.

With the increasing concerns of climate change, natural disasters, and energy disruptions, buildings need to be resilient. Architects and decision-makers are often on the lookout for new ways of enhancing building projects, particularly when it comes to comfort, energy efficiency, and safety. Concrete hollow-core slabs help establish value-added groundwork for a resilient building, as the material is well-known for its durability, resiliency, and thermal mass. Opting for factory-made precast concrete also ensures a consistent product throughout the entire structure. Historically used for multi-storey buildings, hollow cores are now being seen in an increased variety of projects.

These products are prestressed slabs of concrete, with circular openings forming hollow silos within. This opening runs the length of the slab, making the unit ideal for equipping electrical wiring or mechanical ventilation. Highly versatile, hollow-core slabs can also be altered to include plumbing and even sprinkler systems within the building—useful for high-rise apartment buildings, classrooms, and institutions requiring one- to two-hour fire ratings between floors. Typically 1.2 m (4 ft) in width and 9.1 m (30 ft) in length, these 203- to 254-mm (8- to 10-in.) thick units are ideal for schools, industrial buildings, offices, hotels, and multi-storey apartments.

Why use hollow-core slabs?

Precast hollow-core concrete planks require transportation to deliver and cranes to install, which can be a roadblock for some builders. However, traditionally, poured concrete and other flooring systems come with their own sets of challenges, such as interruptions and delays due to poor weather conditions, increased labour time, and inconsistent forms. As hollow-core slabs are manufactured indoors in a factory-controlled environment, they increase efficiency, providing a consistent form for builders to use. They can be delivered and installed in any weather.

As an additional benefit, the voids in hollow concrete slabs not only reduce the amount of material used, but also make it lighter than non-hollowed precast forms. Using less raw material, precast hollow-core slabs make a positive addition to a project's sustainability.

Furthermore, integrating hollow-core planks with a building's conventional HVAC system can leverage the naturally occurring thermal properties that are in dormant concrete floors.

Photo courtesy Svedas Architects

Dr. Frank J. Hayden School (Burlington, Ont.) benefits from increased ventilation and energy storage through use of hollow-core slabs.

> A hollow-core concrete building's thermal mass also makes it more resilient, allowing it to withstand extreme temperature changes and maintain comfort even during failure of heating or cooling systems.

Photos courtesy B&H Architects

This worker is completing an installation of hollow-core slab.

This means more sustainable and efficient heating and cooling methods can be incorporated with no need for new components. Simply combining hollow-core precast and pre-existing or readily available HVAC equipment will suffice.

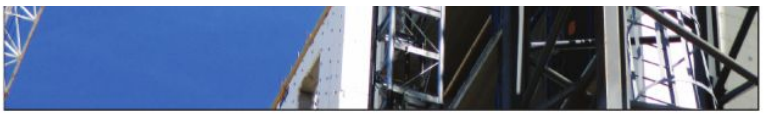
These preformed units also enable builders to respond to tight deadlines, as their congruency makes them easy to place. Given the fact these slabs are formed in a controlled environment, builders can be assured high-quality products are delivered to the construction site. This means hollow-core concrete slabs can evade some of the challenges common with poured concrete—for example, their consistent quality allows for quick installation, with some builders installing up to 929 m^2 (10,000 sf) a day.

While many buildings implementing hollow-core slabs are designed to be rectangular (*e.g.* schools, institutions, and multi-level complexes), the units can also be adapted onsite to unconventional forms such as curves and sloped roofs if they are saw-cut with diamond blades.

Activating thermal mass of concrete

Using concrete in commercial, institutional, and residential buildings is ideal for low-energy design, and for allowing a building to absorb and store energy, thanks to the material's high thermal mass. This quality also means a large amount of energy is required to alter concrete's temperature, making it ideal for a building where the goal is to maintain a consistent interior environment. Concrete works well in passive structures that use an alternative energy source (*e.g.* solar or geothermal), as well as in active buildings integrating hollow-core slabs with the HVAC system to store energy.

A hollow-core concrete building's thermal mass also makes it more resilient than lighter structures, allowing it to withstand extreme temperature changes and maintain comfort even during failure of heating or cooling



The process of installing hollow-core slab.

even during failure of heating or cooling systems. The large surface area of these slabs helps preserve the building's core temperature for an extended period of time. The volumetric thermal capacity of concrete with a density

Photo courtesy Svedas Architects

This City of Burlington library incorporates hollow-core flooring in order to help increase ventilation and thermal comfort.

of 2300 kg/m³ (143 lb/cf) is 2.07 MJ/m³ per K (30.89 Btu/cf per F). In other words, if a building requires the temperature of 1 m³ (35 cf) concrete to be raised to 1 K (1.8 F), it requires approximately 575 W-h (1962 Btu). The benefit of this is if the HVAC system fails, the building can still function and remain comfortable.

In fact, the heat capacity of precast hollow-core slabs is estimated to be about 100 W-h/m² per K (17.6 Btu/sf per F). In a conventional system (*e.g.* steel studs and drywall), the thermal exchange between a room's air and walls has a heat-transfer value of only about 10 W/m² per K (1.76 Btu/hr/sf per F).[1]

How does concrete keep a building cool?

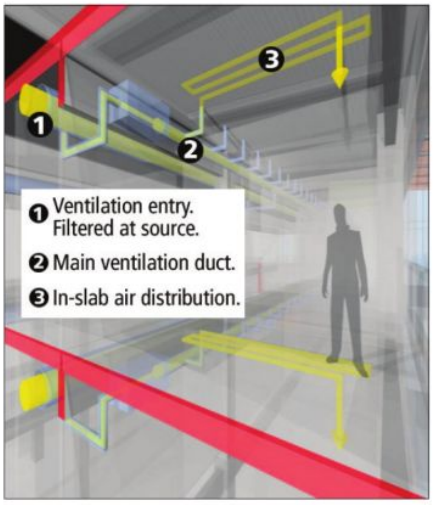
Concrete partially absorbs heat from the structure and its occupants, essentially removing heat from the space and helping naturally cool the building. At some point during the day, supplementary cooling may be required, but for a relatively short time compared to conventional systems.

By design, hollow-core slabs can intake and store cooler nighttime air, then release it when required. The slab acts as a thermal 'battery,' which can harness free cooling when available, and can be mechanically charged at night when conditions are more favourable (*i.e.* when the sun is down and lights are off). As well, for most of the year, the integration of hollow-core slabs with a ventilation system can increase overall air quality by providing an increased flow of fresh air without the need for supplementary heating or cooling.

In summer, cool night air (*i.e.* between 10 and 15 C [50 and 60 F]) can not only be circulated,

Figure 1

Image courtesy Termobuild



Hollow-core slab diagram demonstrating how the slab can be used to connect with HVAC ventilation, lighting, and even telephones to create a smart flooring or ceiling system.

Figure 2

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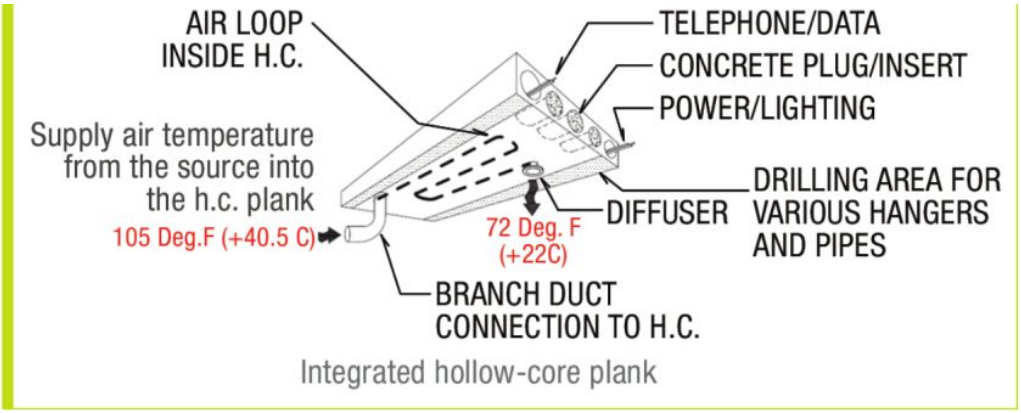


Image courtesy B+H Arch

This figure illustrates how the hollow-core slab system provides a consistent flow of fresh-air ventilation, improving indoor air quality (IAQ).

but also stored in precast floors, as shown in Figure 1. In places where the nighttime air is not cool enough, off-peak air refrigeration may be needed to precool buildings.

When cooling or heating a building, dynamic energy exchange between exterior and interior should be considered. The body heat generated by occupants is highly valuable thermal energy in winter, and can be easily harnessed to maintain temperatures in the desired comfort zone without overheating. When the thermal mass of a building is engaged through a hollow-core slab ventilation system, heat gain generated from occupants, lights, and appliances can be stored for later use. Air is kept clean via filtration and is delivered at slightly lower velocities than with a conventional system, which helps ensure concrete particles are not lifted. Hollow-core slab manufacturing also creates minimal concrete particles in the core area.

Getting off the grid

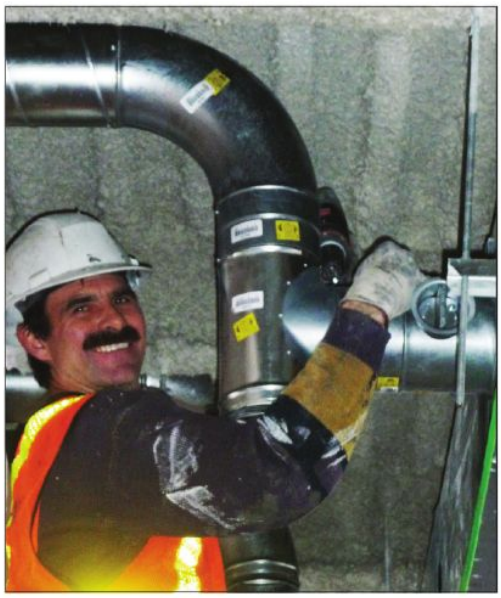
On average, about 75 per cent of the thermal energy available from tempered ventilation air can be absorbed by a hollow-core slab. Consequently, using thermal properties of floors and ceilings as an active battery is less expensive than alternative conventional mechanical systems. At the same time, these systems naturally lend themselves to cost-building, distributing air through their cores. They can also be tied into various conventional HVAC systems to store energy for later use, helping reduce greenhouse gas (GHG) emissions and overall energy costs. Incorporating systems with a high thermal mass is one way to adapt to the impact of rising temperatures and unstable weather patterns directly linked to climate change.

Buildings implementing these methods can typically withstand significant outdoor temperature changes and even energy disruptions with minimal impact, as the energy storage feature of hollow-core slabs enables building occupants to remain 'off-grid' for extended periods. Commonly used in floors and roofs, these systems can be paired with a ventilation system to provide both the thermal mass

naturally lend themselves to cost effective, net-zero construction.

Radiant air-conditioning systems with thermal storage work intuitively with fan-assisted ventilation systems. The ventilation will push treated fresh air through a series of main ducts, fed into branch ducts formed within the hollow-core slabs of ceilings or floors (Figure 2). As air passes along the ducts, the concrete warms or cools the fresh air before supplying it to the occupied space. The building residents will benefit from both better air quality and controlled temperatures.

Precast, prestressed hollow-core planks can be seamlessly integrated into a



Completing a hybrid metal-to-concrete connection, connecting the hollow-core slabs to the HVAC system.

valued in concrete and an energy storage solution. This type of material adapts well to hot, cold, and humid environments, as it responds to the needs of various occupancy types and climatic zones.

Effectively, hollow-core slabs are an economical solution that can move an inert floor or roof from an idle state to an intelligent one by capturing, storing, and releasing low-grade energy upon demand. This can reduce or eliminate the need for heating and cooling from non-renewable sources and spread the release of energy over a longer time. In case of a power failure or other conditions, without the start-stop approach typical with conventional systems. This type of system is designed to gently adjust supply air temperature for maximum indoor comfort while minimizing energy use, thereby reducing energy intensity use per square metre in any building—especially net-zero structures.

Conclusion

With an emerging trend toward stricter energy consumption guidelines, carbon footprint reduction, resilience, and 'smart city' initiatives, improving energy infrastructure management is a valuable part of the strategic response to external change. Hollow-core slabs can become a vital part of this solution as builders continue to shift their focus toward creating net-zero structures.

Most builders are not looking simply for a consistent, easy-to-use structure, but actively seeking products that will help guide the way to a net-zero building. Rapidly increasing energy prices have created a market interested not only in alternative energy sources, but also in how to reduce energy use. By integrating otherwise-independent products that usually do not interact, architects, developers, and decision-makers are encouraged to shift their focus from individual products to a combined approach that meets broader needs.

Notes

longer time. In case of a power failure or other climate-change-related events, hollow-core concrete slabs will continue to release stored energy, ensuring the building is habitable and providing a sustainable operation solution.

Incorporating intelligent software

One of the key advantages of hollow-core slabs is the system can be tied in directly with conventional HVAC. When HVAC and hollow-core slab heating and cooling capabilities are paired with intelligent software solutions, the harnessing and release of free energy can further be optimised (*e.g.* by occurring at peak hours or when most needed). This could considerably decrease overall use of the HVAC system. In fact, the need for larger-capacity equipment can be reduced by as much as 45 to 50 per cent.

Adding the intuitive response of an intelligent software system can more smoothly maintain desired comfort level and respond to changing

[1] It is important to note the first units are energy or heat capacity of the hollow-core slab, shown in Btu or W-h. The second is the energy transfer rate, shown in Btu/hr or W.

Jack Laken, P.Eng., B.Sc., brings together 30 years of experience from his engineering and construction backgrounds to develop innovative building solutions for the commercial, industrial, and residential sectors via his company, Termobuild. His methods are devoted to achieving the desired outcome for new buildings and a smooth conversion from conventional to high performance without introducing new and costly indoor comfort systems. Laken can be reached via e-mail at jlaken@termobuild.com.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